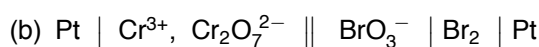
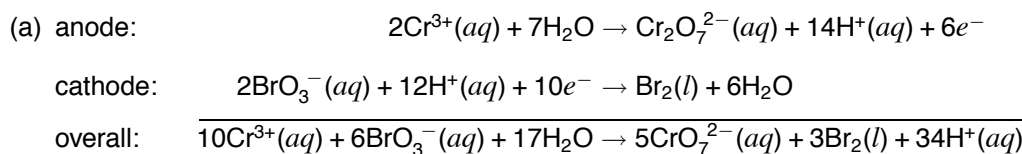


11. Electroplating: GILB E 4, SHAK 4 212–244
12. Electrolysis of water solutions: SHAK 4 170–181, 205–209
13. Commercial voltaic cells: SHAK 4 115, J. Chem. Educ. 67 158 (1990)
14. Corrosion: GILB G 83, M 261

SUMMARY PROBLEM



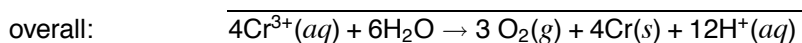
(c) $E^\circ = E_{\text{ox}}^\circ + E_{\text{red}}^\circ = 0.15 \text{ V}$

(d) $E^\circ = \frac{-\Delta G^\circ}{nF}$; $0.15 \text{ V} = \frac{-\Delta G^\circ}{30(9.648 \times 10^4 \text{ J/mol} \cdot \text{V})}$; $\Delta G^\circ = 4.3 \times 10^2 \text{ kJ/mol}$

$$E^\circ = -\frac{0.0257 \text{ V}}{n} \ln K; \quad 0.15 \text{ V} = \frac{0.0257 \text{ V}}{30} \ln K; \quad K = 1.1 \times 10^{76}$$

(e) $E = E^\circ - \frac{0.0257}{n} \ln \frac{[\text{Cr}_2\text{O}_7^{2-}]^5 [\text{H}^+]^{34}}{[\text{Cr}^{3+}]^{10} [\text{BrO}_3^-]^6}$; $[\text{H}^+] = 10^{+0.301} = 2.00$

$$E = 0.15 - \frac{0.0257}{30} \ln \frac{(0.1500)^5 (2.00)^{34}}{(0.1500)^{10} (0.1500)^6} = 0.11 \text{ V}$$



(g) $22.00 \text{ g Cr} \times \frac{1 \text{ mol Cr}}{52.00 \text{ g Cr}} \times \frac{3 \text{ mol } e^-}{1 \text{ mol Cr}} \times \frac{9.648 \times 10^4 \text{ C}}{1 \text{ mol } e^-} \times \frac{1 \text{ A} \cdot \text{s}}{1 \text{ C}} \times \frac{1}{5.4 \text{ A}} = 2.3 \times 10^4 \text{ s} \times \frac{1 \text{ h}}{3600 \text{ s}} = 6.3 \text{ h}$

(h) $3.75 \text{ A} \times 45 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} \times \frac{1 \text{ C}}{1 \text{ A} \cdot \text{s}} \times \frac{1 \text{ mol } e^-}{9.648 \times 10^4 \text{ C}} \times \frac{1 \text{ mol Cr}}{3 \text{ mol } e^-} = 0.035 \text{ mol Cr}$

So, 0.035 mol Cr^{3+} converted to Cr.

Before electrolysis, $\text{mol Cr}^{3+} = \text{mol Cr}(\text{NO}_3)_3 = 1.25 \text{ L} \times (0.787 \text{ mol/L}) = 0.984$.

After electrolysis, $\text{mol Cr}^{3+} = 0.984 - 0.035 = 0.949$. Then, $[\text{Cr}^{3+}] = \frac{0.949 \text{ mol}}{1.25 \text{ L}} = 0.759 \text{ M}$.

$$0.035 \text{ mol Cr plated} \times \frac{12 \text{ mol H}^+}{4 \text{ mol Cr}} = 0.105 \text{ mol H}^+$$

$$[\text{H}^+] = \frac{0.105 \text{ mol}}{1.25 \text{ L}} = 0.084 \text{ M}; \quad \text{pH} = 1.09$$

PROBLEMS

1. (a) $3 \text{Mg}(s) + 2 \text{Sc}^{3+}(aq) \rightarrow 3 \text{Mg}^{2+}(aq) + 2 \text{Sc}(s)$
 (b) $\text{Sn}(s) + \text{Pb}^{2+}(aq) \rightarrow \text{Sn}^{2+}(aq) + \text{Pb}(s)$
 (c) $6 \text{Cl}^{-}(aq) + 2 \text{NO}_3^{-}(aq) + 8 \text{H}^{+}(aq) \rightarrow 3 \text{Cl}_2(g) + 2 \text{NO}(g) + 4 \text{H}_2\text{O}$

3. (a) Zn anode, surrounded by Zn^{2+} ions; Cd cathode surrounded by Cd^{2+} ions. Cations move to Cd cathode, anions to Zn anode. Electrons move through the external circuit from Zn to Cd.
 (b) Cu anode, surrounded by Cu^{2+} ions; Au cathode surrounded by AuCl_4^{-} ions, Cl^{-} ions. Cations move to Au cathode, anions to Cu anode. Electrons move through the external circuit from Cu to Au.
 (c) Fe anode, surrounded by OH^{-} ions, Fe^{2+} ions, $\text{Fe}(\text{OH})_2(s)$; Cu cathode surrounded by OH^{-} ions, Cu^{2+} ions, $\text{Cu}(\text{OH})_2(s)$. Cations move to Cu cathode, anions to Fe anode. Electrons move through the external circuit from Fe to Cu.

5. (a) through the external circuit (b) anode (c) Fe

7. Cations move to Cr cathode, anions to Mn anode. Electrons move through the external circuit from Mn to Cr.

$$\begin{array}{r} \text{Mn}(s) \rightarrow \text{Mn}^{2+}(aq) + 2e^{-} \\ \text{Cr}^{3+}(aq) + 3e^{-} \rightarrow \text{Cr}(s) \\ \hline 3 \text{Mn}(s) + 2 \text{Cr}^{3+}(aq) \rightarrow 3 \text{Mn}^{2+}(aq) + 2 \text{Cr}(s) \\ \text{Mn} \mid \text{Mn}^{2+} \parallel \text{Cr}^{3+} \mid \text{Cr} \end{array}$$

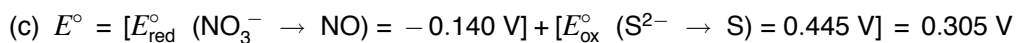
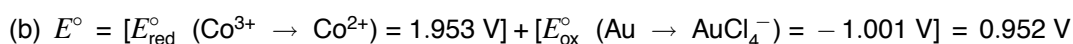
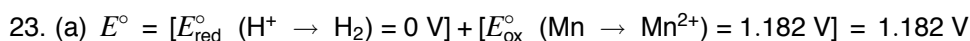
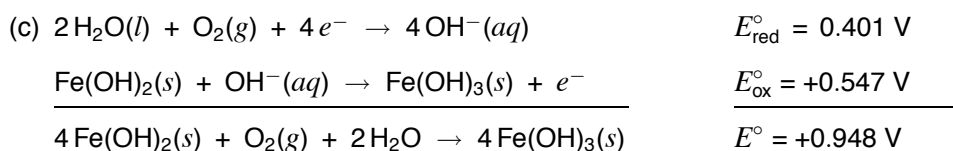
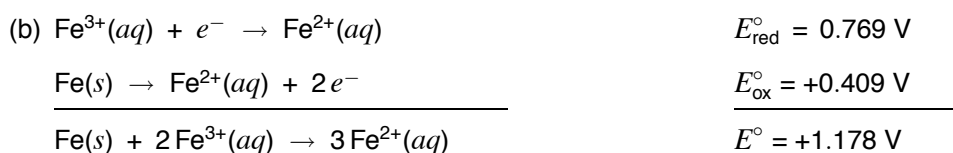
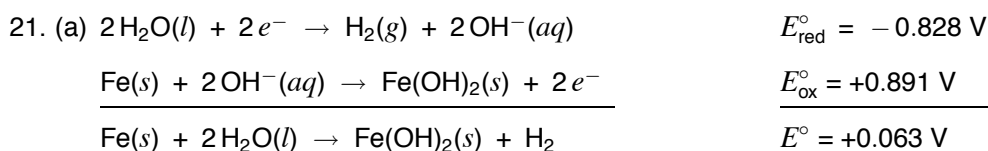
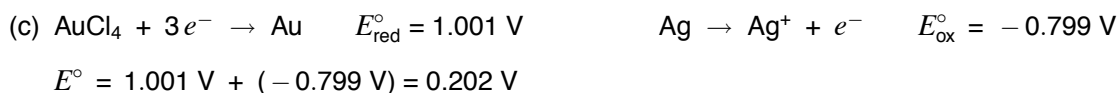
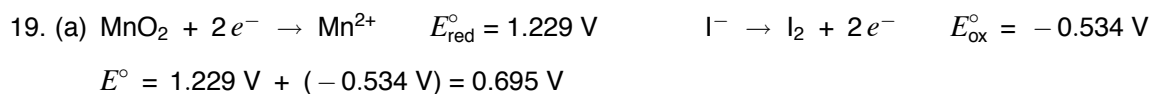
9. (a) NO_3^{-} (b) S (c) MnO_2 (d) acidic solution

11. $\text{PbSO}_4 < \text{Br}^{-} < \text{H}_2\text{S} < \text{Co} < \text{Zn}$

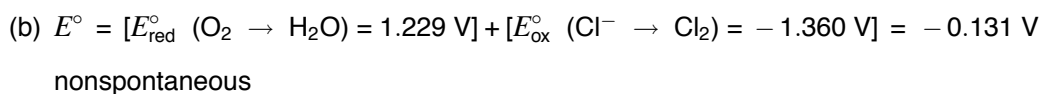
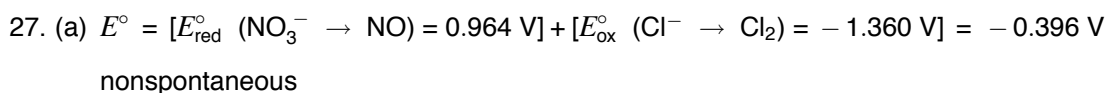
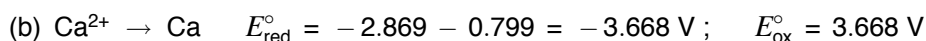
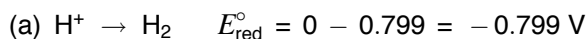
13. Oxidizing agents: $\text{Cr}^{3+} < \text{Sn}^{2+} < \text{Br}_2$; Reducing agents: $\text{Cr}^{3+} < \text{Hg} < \text{Sn}^{2+} < \text{H}_2$

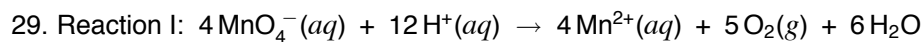
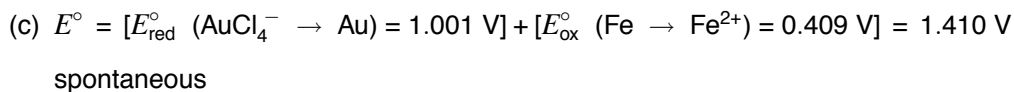
15. (a) Al^{3+} (b) Ce^{4+} (c) Al (d) Ce^{3+}
 (e) yes (f) no (g) Ce^{4+} , Hg_2^{2+} , Ag^{+} (h) Ni, Sn, Al

17. (a) $\text{Ag} + \text{I}^{-}$, Ni, Co (b) Ag^{+} , Hg^{2+} , NO_3^{-} , AuCl_4^{-} (c) H_2S , $\text{Ag} + \text{Br}^{-}$, H_2 , Pb

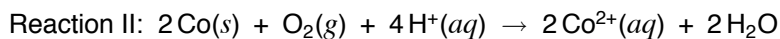


25. If E° for $\text{Ag}^+ \rightarrow \text{Ag} = 0 \text{ V}$, then all cell potentials would decrease by 0.799 V

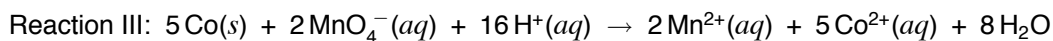




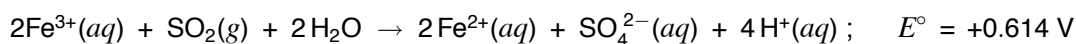
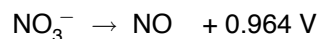
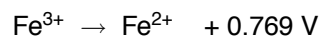
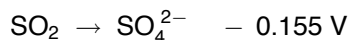
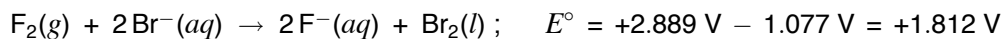
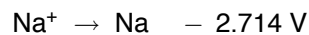
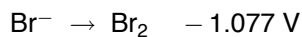
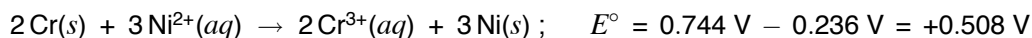
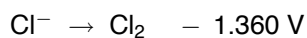
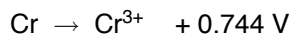
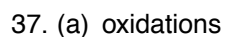
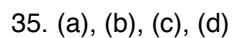
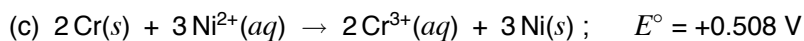
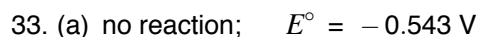
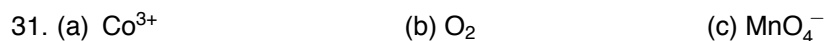
$$E^\circ = E^\circ_{\text{red}} (1) + E^\circ_{\text{ox}} (2) = 1.512 \text{ V} - 1.229 \text{ V} = 0.283 \text{ V}$$



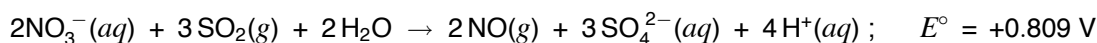
$$E^\circ = E^\circ_{\text{red}} (2) + E^\circ_{\text{ox}} (3) = 1.229 \text{ V} + 0.282 \text{ V} = 1.511 \text{ V}$$



$$E^\circ = E^\circ_{\text{red}} (1) + E^\circ_{\text{ox}} (3) = 1.512 \text{ V} + 0.282 \text{ V} = 1.794 \text{ V}$$



or



39. Substitute into the formulas: $\Delta G^\circ = -nFE^\circ$; $E^\circ = \frac{0.0257}{n} \ln K$

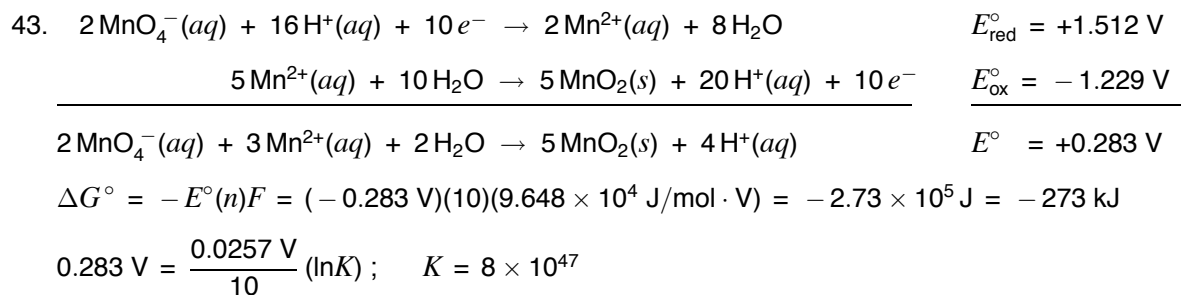
	ΔG°	E°	K
(a)	19 kJ	-0.098 V	5×10^{-4}
(b)	-6.8 kJ	0.035 V	15
(c)	5.8 kJ	-0.030 V	0.095

41. (a) $E^\circ = \frac{-\Delta G^\circ}{nF} = \frac{-25 \times 10^3 \text{ J}}{1(9.648 \times 10^4 \text{ J/mol} \cdot \text{V})} = -0.259 \text{ V}$

(b) $n = 2$ means E° is $\frac{1}{2}$ of E° obtained in (a). $E^\circ = -0.130 \text{ V}$

(c) $n = 4$ means E° is $\frac{1}{4}$ of E° obtained in (a). $E^\circ = -0.0648 \text{ V}$

No effect on E° but ΔG° is proportional to n .



45. (a) $\Delta G^\circ = (-0.695 \text{ V})(2)((9.648 \times 10^4 \text{ J/mol} \cdot \text{V})) = -1.34 \times 10^5 \text{ J} = -134 \text{ kJ}$

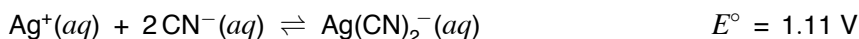
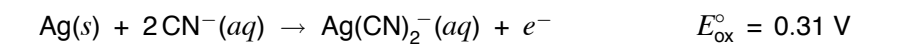
(b) $\Delta G^\circ = (-0.383 \text{ V})(2)((9.648 \times 10^4 \text{ J/mol} \cdot \text{V})) = -7.39 \times 10^4 \text{ J} = -73.9 \text{ kJ}$

(c) $\Delta G^\circ = (-0.202 \text{ V})(3)((9.648 \times 10^4 \text{ J/mol} \cdot \text{V})) = -5.85 \times 10^4 \text{ J} = -58.5 \text{ kJ}$

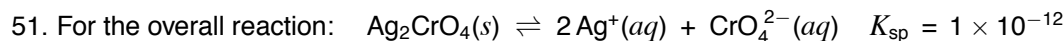
47. (a) $\ln K = \frac{nE^\circ}{0.0257} = \frac{(2)(0.063 \text{ V})}{0.0257 \text{ V}}$; $K = 1.3 \times 10^2$

(b) $\ln K = \frac{(2)(1.178 \text{ V})}{0.0257 \text{ V}}$; $K = 6.5 \times 10^{39}$

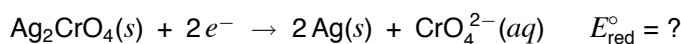
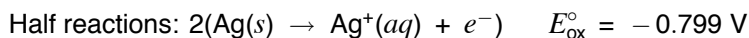
(c) $\ln K = \frac{(4)(0.948 \text{ V})}{0.0257 \text{ V}}$; $K = 1 \times 10^{64}$



$$\ln K = \frac{nE^\circ}{0.0257} = \frac{(1)(1.11 \text{ V})}{0.0257 \text{ V}}; \quad K = 5.8 \times 10^{18}$$



$$E^\circ = \frac{0.0257}{2} \ln (1 \times 10^{-12}) = -0.35 \text{ V}$$



$$-0.35 \text{ V} = -0.799 \text{ V} + E_{\text{red}}^\circ; \quad E_{\text{red}}^\circ = 0.45 \text{ V}$$

53. (a) $E^\circ = -1.498 \text{ V} + 1.763 \text{ V} = +0.265 \text{ V}$

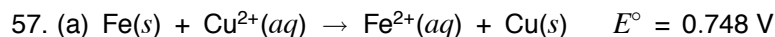
(b) $E = +0.265 \text{ V} - \frac{0.0257}{6} \ln \frac{[\text{Au}^{3+}]^2}{[\text{H}_2\text{O}_2]^3[\text{H}^+]^6}$

(c) $E = +0.265 \text{ V} - \frac{0.0257}{6} \ln \frac{(0.250)^2}{(1.50)^3(1.25)^6} = +0.288 \text{ V}$

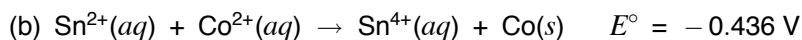
55. (a) $E^\circ = -0.769 \text{ V} + 1.763 \text{ V} = +0.994 \text{ V}$

(b) $E = +0.994 \text{ V} - \frac{0.0257}{2} \ln \frac{[\text{Fe}^{3+}]^2}{[\text{Fe}^{2+}]^2[\text{H}_2\text{O}_2][\text{H}^+]^2}$

(c) $E = +0.994 \text{ V} - \frac{0.0257}{2} \ln \frac{(0.199)^2}{(0.00813)^2(0.914)(1.32 \times 10^{-3})^2} = +0.740 \text{ V}$



$$E = E^\circ - \frac{0.0257}{2} \ln \frac{[\text{Fe}^{2+}]}{[\text{Cu}^{2+}]} = 0.748 \text{ V} - \frac{0.0257}{2} \ln \frac{(0.010)}{(0.10)} = 0.778 \text{ V}$$

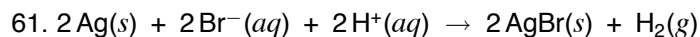


$$E = E^\circ - \frac{0.0257}{2} \ln \frac{[\text{Sn}^{4+}]}{[\text{Sn}^{2+}][\text{Co}^{2+}]} = -0.436 \text{ V} - \frac{0.0257}{2} \ln \frac{(0.010)}{(0.10)(0.10)} = -0.436 \text{ V}$$

$$59. E^{\circ} = 0.161 \text{ V} + (-0.154 \text{ V}) = 0.007 \text{ V}$$

$$E = 0.007 \text{ V} - \frac{0.0257 \text{ V}}{2} \ln \frac{[\text{Sn}^{4+}][\text{Cu}^{+}]^2}{[\text{Sn}^{2+}][\text{Cu}^{2+}]^2}$$

$$0 = 0.007 \text{ V} - \frac{0.0257 \text{ V}}{2} \ln \frac{(0.200)(0.200)^2}{(0.200)[\text{Cu}^{2+}]^2}; \quad [\text{Cu}^{2+}] = 0.15 \text{ M}$$



$$E^{\circ} = 0.000 \text{ V} + (-0.073 \text{ V}) = -0.073 \text{ V}$$

$$-0.030 \text{ V} = -0.0073 \text{ V} - \frac{0.0257 \text{ V}}{2} \ln \frac{P_{\text{H}_2}}{[\text{Br}^{-}]^2[\text{H}^{+}]^2}$$

$$-0.030 \text{ V} = -0.0073 \text{ V} - \frac{0.0257 \text{ V}}{2} \ln \frac{1.0}{(3.73)^2[\text{H}^{+}]^2}; \quad [\text{H}^{+}] = 1.4 \text{ M}$$

$$63. (a) E^{\circ} = 1.512 \text{ V} + (-1.077 \text{ V}) = 0.435 \text{ V}; \quad \text{spontaneous}$$

$$(b) E = 0.435 \text{ V} - \frac{0.0257 \text{ V}}{10} \ln \frac{[\text{Mn}^{2+}]^2}{[\text{MnO}_4^{-}]^2[\text{H}^{+}]^{16}[\text{Br}^{-}]^{10}}$$

$$E = 0.435 \text{ V} - \frac{0.0257 \text{ V}}{10} \ln \frac{(0.100)^2}{(0.100)^2(0.010)^{16}(0.100)^{10}} = 0.186 \text{ V}; \quad \text{spontaneous}$$

$$(c) E = 0.435 \text{ V} - \frac{0.0257 \text{ V}}{10} \ln \frac{(0.100)^2}{(0.100)^2(1.0 \times 10^{-5})^{16}(0.100)^{10}} = -0.098 \text{ V}; \quad \text{nonspontaneous}$$

$$(d) E = 0 \text{ V at equilibrium}; \quad 0 \text{ V} = 0.435 \text{ V} - \frac{0.0257 \text{ V}}{10} \ln \frac{(0.100)^2}{(0.100)^2[\text{H}^{+}]^{16}(0.100)^{10}}$$

$$[\text{H}^{+}] = 1 \times 10^{-4} \text{ M}; \quad \text{pH} = 4.0$$

$$65. (a) E^{\circ} = -0.799 \text{ V} + 0.339 \text{ V} = -0.460 \text{ V}$$

$$(b) 0.060 \text{ V} = -0.460 \text{ V} - \frac{0.0257 \text{ V}}{2} \ln \frac{[\text{Ag}^{+}]^2}{1.0}; \quad [\text{Ag}^{+}] = 1.6 \times 10^{-9} \text{ M}$$

$$(c) K_{\text{sp}} = [\text{Ag}^{+}][\text{Cl}^{-}] = (0.10)(1.6 \times 10^{-9}) = 1.6 \times 10^{-10}$$

$$67. (a) \text{Al}^{3+}(aq) + 3 e^{-} \rightarrow \text{Al}(s); \quad 1.000 \times 10^4 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3.00 \text{ mol } e^{-}}{1 \text{ mol Al}} = 1112 \text{ mol } e^{-}$$

$$(b) 1 \text{ da} \times \frac{24 \text{ h}}{1 \text{ da}} \times \frac{3600 \text{ s}}{1 \text{ h}} = 86400 \text{ s}; \quad 1112 \text{ mol } e^{-} \times \frac{9.648 \times 10^4 \text{ C}}{1 \text{ mol } e^{-}} \times \frac{1 \text{ A} \cdot \text{s}}{1 \text{ C}} \times \frac{1}{86400 \text{ s}} = 1242 \text{ A}$$

$$(c) 2 \text{Al}_2\text{O}_3(s) \rightarrow 4 \text{Al}(s) + 3 \text{O}_2(g); \quad 1.000 \times 10^4 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3 \text{ mol O}_2}{4 \text{ mol Al}} = 278.0 \text{ mol O}_2$$

$$69. (a) 5.0 \text{ A} \times 10.0 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} \times \frac{1 \text{ C}}{1 \text{ A} \cdot \text{s}} = 3.0 \times 10^3 \text{ C}$$

$$(b) \text{M}^{3+} + 3e^- \rightarrow \text{M}; \quad 3.0 \times 10^3 \text{ C} \times \frac{1 \text{ mol } e^-}{9.648 \times 10^4 \text{ C}} \times \frac{1 \text{ mol M}}{3 \text{ mol } e^-} = 0.01036 \text{ mol M}$$

$$\text{MM} = (1.19 \text{ g}) / 0.01036 \text{ mol} = 1.1 \times 10^2 \text{ g/mol}$$

$$71. (a) 2 \text{ h} + 25 \text{ min} = 8700 \text{ s}$$

$$2.00 \text{ A} \times 8700 \text{ s} \times \frac{1 \text{ C}}{1 \text{ A} \cdot \text{s}} \times \frac{1 \text{ mol } e^-}{9.648 \times 10^4 \text{ C}} \times \frac{1 \text{ mol Ag}}{1 \text{ mol } e^-} \times \frac{107.9 \text{ g Ag}}{1 \text{ mol Ag}} \times 0.82 = 16.0 \text{ g Ag}$$

$$(b) 16.0 \text{ g} \times \frac{1 \text{ cm}^3}{10.5 \text{ g}} = 1.52 \text{ cm}^3; \quad \text{thickness} = \frac{1.52 \text{ cm}^3}{6.25 \text{ cm}^2} = 0.243 \text{ cm}$$

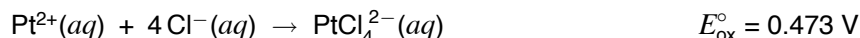
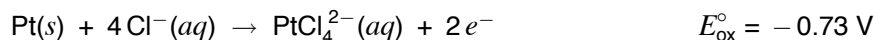
$$73. (a) 1 \text{ h} + 22 \text{ min} = 4920 \text{ s}$$

$$6.00 \text{ A} \times 4920 \text{ s} \times \frac{1 \text{ C}}{1 \text{ A} \cdot \text{s}} \times \frac{1 \text{ mol } e^-}{9.648 \times 10^4 \text{ C}} \times \frac{1 \text{ mol Pb}}{2 \text{ mol } e^-} \times \frac{207.2 \text{ g Pb}}{1 \text{ mol Pb}} = 31.7 \text{ g Pb}$$

$$(b) 12.0 \text{ V} \times \frac{1 \text{ J}}{\text{C} \times \text{V}} \times 4920 \text{ s} \times 6.00 \text{ A} \times \frac{1 \text{ C}}{\text{A} \cdot \text{s}} \times \frac{1 \text{ kWh}}{3.600 \times 10^6 \text{ J}} = 0.0984 \text{ kWh}$$

$$75. \text{ Calculate } E^\circ \text{ for the reaction: } \text{Pt}^{2+}(\text{aq}) + 4 \text{Cl}^-(\text{aq}) \rightarrow \text{PtCl}_4^{2-}(\text{aq})$$

$$E^\circ = \frac{0.0257 \text{ V}}{n} \ln K = \frac{0.0257 \text{ V}}{2} \ln (1 \times 10^{16}) = 0.473 \text{ V}$$



$$0.473 \text{ V} = E^\circ_{\text{red}} + (-0.73 \text{ V}); \quad E^\circ_{\text{red}} = 1.20 \text{ V}$$

$$77. \text{ mol H}_2 = \frac{(10.00 \text{ L})(0.924 \text{ atm})}{(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(273 + 22) \text{ K}} = 0.382$$

$$0.382 \text{ mol H}_2 \times \frac{2 \text{ mol } e^-}{1 \text{ mol H}_2} \times \frac{9.648 \times 10^4 \text{ C}}{1 \text{ mol } e^-} \times \frac{1 \text{ A} \cdot \text{s}}{1 \text{ C}} \times \frac{1}{12.0 \text{ A}} = 6143 \text{ s} = 1.71 \text{ h}$$

$$79. 2.00 \text{ h} \times \frac{3600 \text{ s}}{1 \text{ h}} \times 2.00 \text{ A} \times \frac{1 \text{ C}}{1 \text{ A} \cdot \text{s}} = 1.44 \times 10^4 \text{ C}$$

$$\text{mol } e^- = 28.8 \text{ g Au} \times \frac{1 \text{ mol Au}}{197.0 \text{ g Au}} \times \frac{1 \text{ mol } e^-}{1 \text{ mol Au}} = 0.146$$

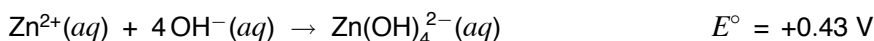
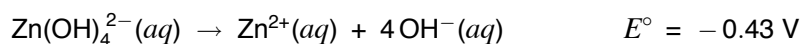
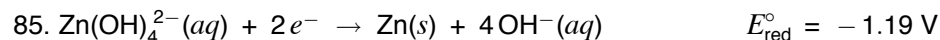
$$\text{Faraday constant} = \frac{\text{C}}{\text{mol } e^-} = \frac{1.44 \times 10^4 \text{ C}}{0.146 \text{ mol } e^-} = 9.85 \times 10^4 \text{ C}$$

$$81. 0.129 \text{ g Cd(OH)}_2 \times \frac{1 \text{ mol Cd(OH)}_2}{146.4 \text{ g Cd(OH)}_2} \times \frac{2 \text{ mol } e^-}{1 \text{ mol Cd}} \times \frac{9.648 \times 10^4 \text{ C}}{1 \text{ mol } e^-} = 170.0 \text{ C}$$

$$170.0 \text{ C} \times \frac{1 \text{ A} \cdot \text{s}}{1 \text{ C}} \times \frac{1}{0.175 \text{ A}} = 971 \text{ s} = 0.270 \text{ h}$$

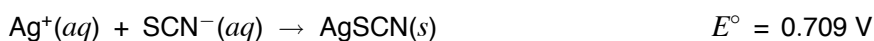
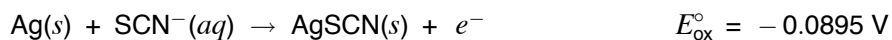
$$83. \text{ mol M} = 0.600 \text{ A} \times 1 \text{ h} \times \frac{3600 \text{ s}}{1 \text{ h}} \times \frac{1 \text{ C}}{1 \text{ A} \cdot \text{s}} \times \frac{1 \text{ mol } e^-}{9.648 \times 10^4 \text{ C}} \times \frac{1 \text{ mol M}}{1 \text{ mol } e^-} = 0.0224$$

$$\text{MM of M} = 2.42 \text{ g} / 0.0224 \text{ mol} = 108 \text{ g/mol}$$



$$\ln K = \frac{nE^\circ}{0.0257 \text{ V}} = \frac{(2)(0.43 \text{ V})}{0.0257 \text{ V}}; \quad K = 3 \times 10^{14}$$

87. (d)



$$\ln \frac{1}{K_{\text{sp}}} = \frac{(1)(0.709 \text{ V})}{0.0257 \text{ V}}; \quad K = 1 \times 10^{-12}$$

91. (a) EQ (b) LT (c) GT (d) EQ (e) MI

93. Assume 10.00 A for 10.00 min (600.0 s) as total current.

$$\text{For Sn, current supplied} = (10.00 \text{ A})(600.0 \text{ s})(0.200) = 1.20 \times 10^3 \text{ A} \cdot \text{s} = 1.20 \times 10^3 \text{ C}$$

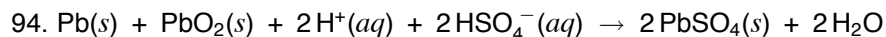
$$\text{mass Sn} = 1.20 \times 10^3 \text{ C} \times \frac{1 \text{ mol } e^-}{9.648 \times 10^4 \text{ C}} \times \frac{1 \text{ mol Sn}^{2+}}{2 \text{ mol } e^-} \times \frac{118.69 \text{ g Sn}}{1 \text{ mol Sn}^{2+}} = 0.738 \text{ g}$$

$$\text{For Cu, current supplied} = (10.00 \text{ A})(600.0 \text{ s})(0.800) = 4.80 \times 10^3 \text{ A} \cdot \text{s} = 4.80 \times 10^3 \text{ C}$$

$$\text{mass Cu} = 4.8 \times 10^3 \text{ C} \times \frac{1 \text{ mol } e^-}{9.648 \times 10^4 \text{ C}} \times \frac{1 \text{ mol Cu}^{2+}}{2 \text{ mol } e^-} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}^{2+}} = 1.58 \text{ g}$$

$$\text{Total mass} = (1.58 + 0.738) \text{ g} = 2.32 \text{ g}$$

$$\% \text{ Sn} = \frac{0.738 \text{ g}}{2.32 \text{ g}} \times 100\% = 31.8\%; \quad \% \text{ Cu} = 100 - 31.8 = 68.2\%$$



$$\Delta G^\circ = -371.4 \text{ kJ (see page 502)}; \quad E^\circ = -\frac{3.741 \times 10^5 \text{ J/mol}}{(2)(9.648 \times 10^4 \text{ J/mol} \cdot \text{V})} = 1.925 \text{ V}$$

Consider 1000.0 g of solution: $\text{mol H}_2\text{SO}_4 = 380 \text{ g} \times \frac{1 \text{ mol}}{98.08 \text{ g}} = 3.87$

$$V = 1000.0 \text{ g} \times \frac{1 \text{ cm}^3}{1.286 \text{ g}} \times \frac{1 \text{ L}}{1000 \text{ cm}^3} = 0.778 \text{ L}; \quad [\text{H}_2\text{SO}_4] = \frac{3.87 \text{ mol}}{0.778 \text{ L}} = 4.98 \text{ M} = [\text{H}^+] = [\text{HSO}_4^-]$$

$$E = 1.925 \text{ V} - \frac{0.0257 \text{ V}}{2} \ln \frac{1}{(4.98)^4} = 2.007 \text{ V}$$

95. (a) $E^\circ = 0.621 \text{ V}$

(b) $[\text{Zn}^{2+}]$ increases, $[\text{Sn}^{2+}]$ decreases

(c) $0 = 0.621 \text{ V} - \frac{0.0257 \text{ V}}{2} \ln Q; \quad Q = 1 \times 10^{21}$

(d) $[\text{Zn}^{2+}] = 2.0 \text{ M}; \quad [\text{Sn}^{2+}] = 2 \times 10^{-21} \text{ M}$

96. (a) $\Delta G^\circ = -(2)(9.648 \times 10^4 \text{ J/mol} \cdot \text{V})(-0.581 \text{ V}) = 1.12 \times 10^5 \text{ J}$

$$\Delta G^\circ = -(2)(9.648 \times 10^4 \text{ J/mol} \cdot \text{V})(-0.197 \text{ V}) = 0.38 \times 10^5 \text{ J}$$

$$\Delta G_{\text{tot}}^\circ = 1.50 \times 10^5 \text{ J}$$

(b) $E^\circ' = -\frac{1.50 \times 10^5 \text{ J}}{(4)(9.648 \times 10^4 \text{ J/mol} \cdot \text{V})} = -0.389 \text{ V}$

97. anode: $\text{H}_2(g) \rightarrow 2\text{H}^+(aq) + 2e^- \quad E_{\text{ox}} = 0.00 \text{ V} - \frac{0.0257 \text{ V}}{2} \ln (1 \times 10^{-7})^2 = +0.414 \text{ V}$

cathode: $2\text{H}^+(aq) + 2e^- \rightarrow \text{H}_2(g) \quad E_{\text{red}} = 0 \text{ V}$

$$E = +0.414 \text{ V}$$

98. $\text{mol H}_2 = \frac{(1.0 \text{ L})(200 \text{ atm})}{(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(298 \text{ K})} = 8.17$

$$8.17 \text{ mol H}_2 \times \frac{2 \text{ mol } e^-}{1 \text{ mol H}_2} \times \frac{9.648 \times 10^4 \text{ C}}{1 \text{ mol } e^-} \times \frac{1 \text{ A} \cdot \text{s}}{1 \text{ C}} \times \frac{1}{1.5 \text{ A}} = 1.05 \times 10^6 \text{ s} = 12 \text{ days}$$